AD 739930

RESEARCH DIRECTED TOWARD THE DESIGN, DEVELOPMENT, CONSTRUCTION AND INSTALLATION OF INSTRUMENTATION TO STUDY ENERGY SPECTRA OF HIGH ENERGY SOLAR PROTONS IN POLAR CAP EVENTS

THE ARCAS PROTON PAYLOAD

by

Bach Sellers

Jean Luc Hunerwadel

Frederick A. Hanser

PANAMETRICS, INC.
221 Crescent Street
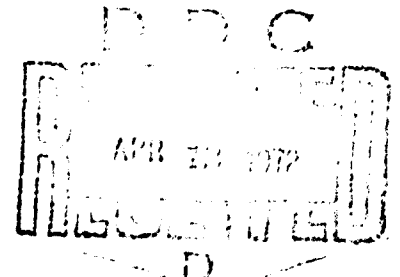Waltham, Massachusetts 02154

SCIENTIFIC REPORT NO. 1

January 1972

Prepared for

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS 01730

Qualified requestors may obtain additional copies from the
Defense Documentation Center.   All others should apply to
the National Technical Information Service.

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Panametrics, Inc.	Unclassified
221 Crescent Street	2b. GROUP
Waltham, Massachusetts 02154	

3. REPORT TITLE RESEARCH DIRECTED TOWARD THE DESIGN, DEVELOPMENT, CONSTRUCTION AND INSTALLATION OF INSTRUMENTATION TO STUDY ENERGY SPECTRA OF HIGH ENERGY SOLAR PROTONS IN POLAR CAP EVENTS - THE ARCAS PROTON PAYLOAD

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Scientific.   Interim

7. AUTHOR(S) (First name, middle initial, last name)
Each Sellers
Jean Luc Hunerwadel
Frederick A. Hanser

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
January 1972	37	5

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
F19628-71-C-0086	
b. Project, Task, Work Unit Nos.	Scientific Report No. 1
5710 - n/a - n/a	
c. DoD Element: 65701H	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d. DoD Subelement: 68920G6300	AFCRL-72-0005

10. DISTRIBUTION STATEMENT

A - Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
This research was supported by the Defense Nuclear Agency	Air Force Cambridge Research Laboratories (LI) L. G. Hanscom Field Bedford, Massachusetts 01730

13. ABSTRACT

A payload for measurement of 7-150 MeV protons and 30-1000 MeV alpha particles has been designed, integrated into, and flown successfully on an Arcas rocket into a solar particle event at Thule on March 29, 1970.

The T. M. system used has only one channel (IRIG E). Data are transmitted and recorded on magnetic tape for each coincidence occurring in a two detector semi-conductor telescope. Subsequently, these data are analyzed to determine the relative energy distributions, the angular distribution, the intensity of the energy distribution and the particle types.

Although the event into which the payload was flown was small, as observed at Thule, it was of sufficient intensity to provide both an operational test and a comparison with interplanetary fluxes as measured from Explorer-41. About 200 coincidences occurred during the 100 seconds centered near apogee. A preliminary estimate of the integral spectrum has been made, and the techniques for complete analysis of the data are presented briefly.

DD FORM **1473** REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Solar Flare Particles						
Protons						
Alpha Particles						
Rocket Research						
Polar Cap Event						

AFCRL-72-0005

RESEARCH DIRECTED TOWARD THE DESIGN, DEVELOPMENT, CONSTRUCTION AND INSTALLATION OF INSTRUMENTATION TO STUDY ENERGY SPECTRA OF HIGH ENERGY SOLAR PROTONS IN POLAR CAP EVENTS

THE ARCAS PROTON PAYLOAD

by

Bach Sellers

Jean Luc Hunerwadel

Frederick A. Hanser

PANAMETRICS, INC.
221 Crescent Street
Waltham, Massachusetts 02154

Contract No. F19628-71-C-0086
Project No. 5710

SCIENTIFIC REPORT NO. 1

January 1972

CONTRACT MONITOR: John A. Sandock
Ionospheric Physics Laboratory

Prepared for

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS 01730

ABSTRACT

A payload for measurement of 7-150 MeV protons and 30-1000 MeV alpha particles has been designed, integrated into, and flown successfully on an Arcas rocket into a solar particle event at Thule on March 29, 1970.

The T. M. system used has only one channel (IRIG E). Data are transmitted and recorded on magnetic tape for each coincidence occurring in a two detector semi-conductor telescope. Subsequently, these data are analyzed to determine the relative energy distributions, the angular distribution, the intensity of the energy distribution and the particle types.

Although the event into which the payload was flown was small, as observed at Thule, it was of sufficient intensity to provide both an operational test and a comparison with interplanetary fluxes as measured from Explorer-41. About 200 coincidences occurred during the 100 seconds centered near apogee. A preliminary estimate of the integral spectrum has been made, and the techniques for complete analysis of the data are presented briefly.

FOREWORD

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

viii

I. INTRODUCTION

I. 1 General Discussion

It is now well known that high energy protons and alpha particles emitted during solar flares are principally responsible for the phenomenon known as a PCA (Polar Cap Absorption) event. It has been established that the highest energy particles emitted during the flare arrive at the earth only a short time after any x-rays emitted. These particles, having energies up to hundreds of MeV, arrive between about 1/2 hour and a few hours after flare initiation. They tend to be highly anisotropic in angular distribution (measured relative to the magnetic field direction). The lower energy particles arrive later and tend toward isotropy in angular distribution. Particles of a few MeV energy may still arrive up to several days after 'are. At any given time of observation on the earth the energy distribution is not found to be monoenergetic in nature. Rather, it is found to be principally constituted of high energy particles early in the flare and low energy particles later. The phenomenon of geomagnetic cutoffs by the earth's magnetic field can modify the low energy portion of the spectrum by denying access to the atmosphere to particles having less than certain energies. Thus, a peak can at times be observed in the spectrum of particles actually interacting with the atmosphere.

The study of PCA events with large sounding rockets such as the Black Brant, Nike-Iroquois, Nike-Tomahawk, etc., is made difficult by the operational problem of timing. While these events do at times occur separated by only a few weeks, at other times the period between events may be several months or more. Time spent on-site awaiting such an event can, therefore, become extended. Observation of the high energy component is made particularly difficult by the necessity for firing within a few hours of flare initiation, i.e., a short reaction time is required.

The present program is intended to mitigate the above operational problems while still providing the required measurements. This

1

is made possible by use of a rather small 4" diameter rocket, the Arcas, which can be fired with very limited range support. This rocket can be checked out at the range and left for many months prior to launch. The launch decision can then be made remotely. A few simple systems tests can be applied by the launch support personnel to verify proper operation before launch. Recovery of the data is straightforward since there is only one T. M. channel, which is recorded on magnetic tape for subsequent analysis.

With a payload of about 8 lbs., the standard Arcas can remain above 50 km for more than 100 seconds. For measurement of 7-150 MeV protons, and higher energy alphas, this is sufficient to make an accurate measurement of the incident spectrum for any event of significance. Of course, the small payload weight and the availability of only one T. M. channel cause a significant design problem. However, once the design has been completed, the operational problem is greatly reduced and reliable data can be obtained without the use of the larger, more expensive, rockets requiring extensive launch support.

I. 2 Basic Description of System

I. 2. 1 Particle Detection Method

The following information is required with regard to incident particle spectra:

     (1) angular distribution

     (2) magnitude (intensity)

     (3) energy distribution

     (4) particle types.

All of this information must be transmitted over a single T. M. channel which, fortunately, has a bandwidth of about 2 kc/sec (IRIG E).

The basic particle detection method is shown in Fig. 1.1. The high energy particles of interest pass through both detectors producing a coincidence, which is used to trigger the system and cause it to analyze
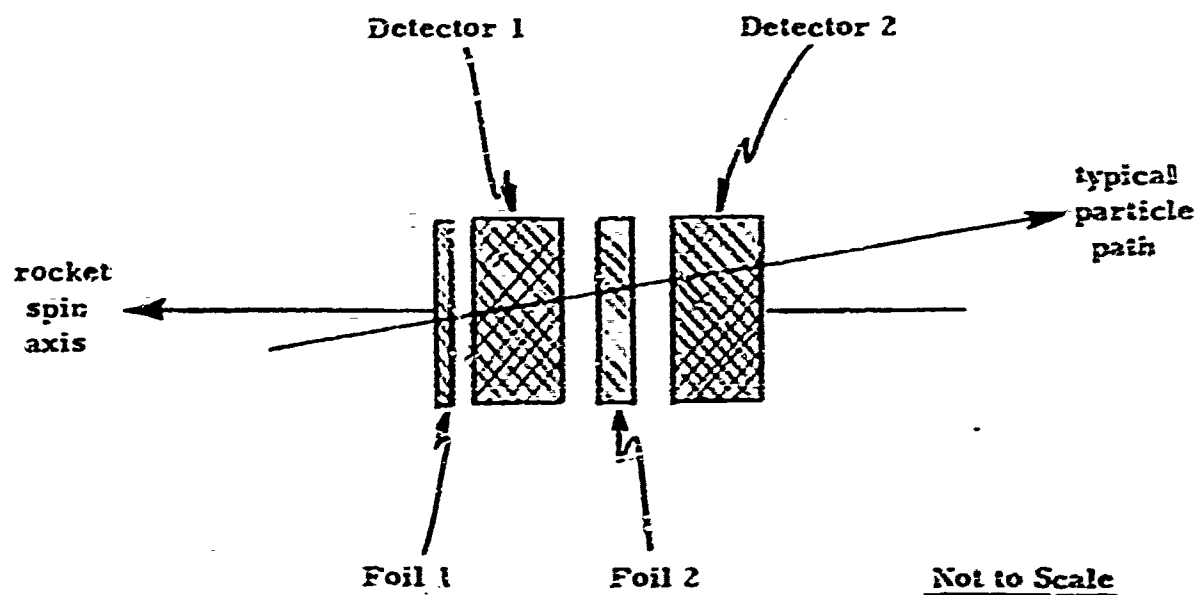
Figure 1.1 High Energy Flare Particle Detector Array Telescope

the output of the two detectors. A magnetometer is located on the rocket axis and is used to obtain the angular orientation of each observed particle relative to the earth's magnetic field. The magnetometer output is telemetered at all times that particle data are not being analyzed. A minimum period of 0.5 msec is provided for magnetometer data following each particle in order that angular data be obtained even in periods of high particle flux. During periods of low flux both the spectrum magnitude and energy distribution can be obtained directly by analysis of indiv idual particles. The total time required to analyze each particle is a maximum of about 10 msec and a minimum of about 2 msec (including minimum magnetometer sample), long times being associated with low energy particles. Thus the maximum rate of analysis of low energy particles (few tens of MeV) will average a few hundred per second regardless of the spectrum intensity. Hence, under these conditions the energy distribution can be obtained from analysis of individual particles, but the intensity cannot. Thus the measured distribution is only relative in this situation. This is taken into account by use of a ratemeter whose output gives the intensity of all observed particles, i.e., it counts all particles having energy exceeding the minimum necessary to trigger the analysis system. The range of the ratemeter is 100-10,000 cps. At low flux levels the ratemeter output is not needed, hence the lower limit of 100 cps. Details of the electronics necessary to accomplish the above, and the actual method of data transmission, are given in the following section.

The method of determining the spectrum magnitude, energy distribution and particle type from the telemetered data is as follows. The detectors used have an area of 3 cm^2 each. The telescope has an opening half-angle of 17.5°, which defines a geometrical factor

$$C = 0.92 \text{ cm}^2\text{-ster.} \qquad (1.1)$$

4

If the count rate is C for all particles exceeding a threshold E (MeV) in a spectrum I $(cm^{-2}$-sec^{-1}-ster$^{-1})$, then I is obtained from the measured value of C by

$$I(> E) = C/G \qquad (1.2)$$

I can be calculated, for purposes of orientation, in the low flux situation by using the value of C found from counting individual particles. For the high flux case I is found by using the value of C from the ratemeter, and it is used to normalize the measured relative energy distribution to determine its absolute magnitude. Clearly, integral flux measurements for various ranges can be calculated from (1.2) if the proper C is known. The basic technique used to measure the particle energy and determine whether it is a proton or alpha particle is as follows. As shown in Fig. 1.1, the telescope consists of two foils and two detectors. The first foil is used to keep out low energy electrons and to remove about 1 MeV from 10 MeV protons. The two detectors are used in coincidence to define the geometrical factor, as noted above. The principal difficulty in a system of this type is discriminating between alphas and protons (and possibly other particles). Without the second foil a high energy alpha particle, $\sim$200-300 MeV, will deposit about the same amount of energy in the detectors as a low energy proton, $\sim$10-15 MeV. By introduction of the second foil it is possible to alter the energy of the low energy protons significantly between the first and second detectors. The energy deposited by the high energy alphas remains nearly the same in each detector, however, because the foil alters their energy very little.

It had originally been intended that the detectors, which are totally depleted silicon, each be 300 microns thick, which would have simplified the data analysis somewhat. As delivered, our measurements indicate that the thickness of Detector 1 is about 225 microns and that of 2 is about 350 microns. The two aluminum foils have an average

5

thickness of 4.0 mils each.

Figures 1.2 and 1.3 show plots of the <u>average</u> energy losses ΔE_1 and ΔE_2 in the two detectors versus incident energy E for both alphas and protons, for particles that can cause a coincidence (penetrate both foils, Detector 1, and deposit at least 0.2 MeV in Detector 2). It is seen that the maximum average energy that a proton can lose in Detector 1 is about 3.2 MeV (a larger amount can be lost in 1, but such a proton cannot produce a coincidence). It is seen, however, that all alphas between 30 MeV and 100 MeV lose more than 3.5 MeV in 1. Thus, this portion of the alpha spectrum is measured with little interference from protons. Some interference will occur because there is some probability that any particle will lose up to several times its average energy loss. Similarly, most protons of energy >20 MeV will lose <1 MeV in the second detector, but essentially no alphas of energy <500 MeV will do so.

A quantity that is useful for differentiating between protons and alphas, particularly in the range in which the energy losses in the detectors would be similar without the foils, is the ratio $\Delta E_1/\Delta E_2$. This is shown in Fig. 1.4. Use of this ratio along with the energy loss plots allows construction of the preliminary logic for determination of the particle type and general energy range, as shown in Table 1.1.

Logic of this type should be applied to each individual event in order to determine its general consistency. Certain events will, due to energy losses significantly greater or less than average, produce "non-average" results, as shown in the table. These particles should be counted in determining the flux - provided it is at least possible to determine their type - however, they should not be used in determining the energy distribution.

The method of determining the actual energy distribution will not be discussed here. It is clear, however, that the ΔE information from each detector can be used to find the most probable event energy E

6
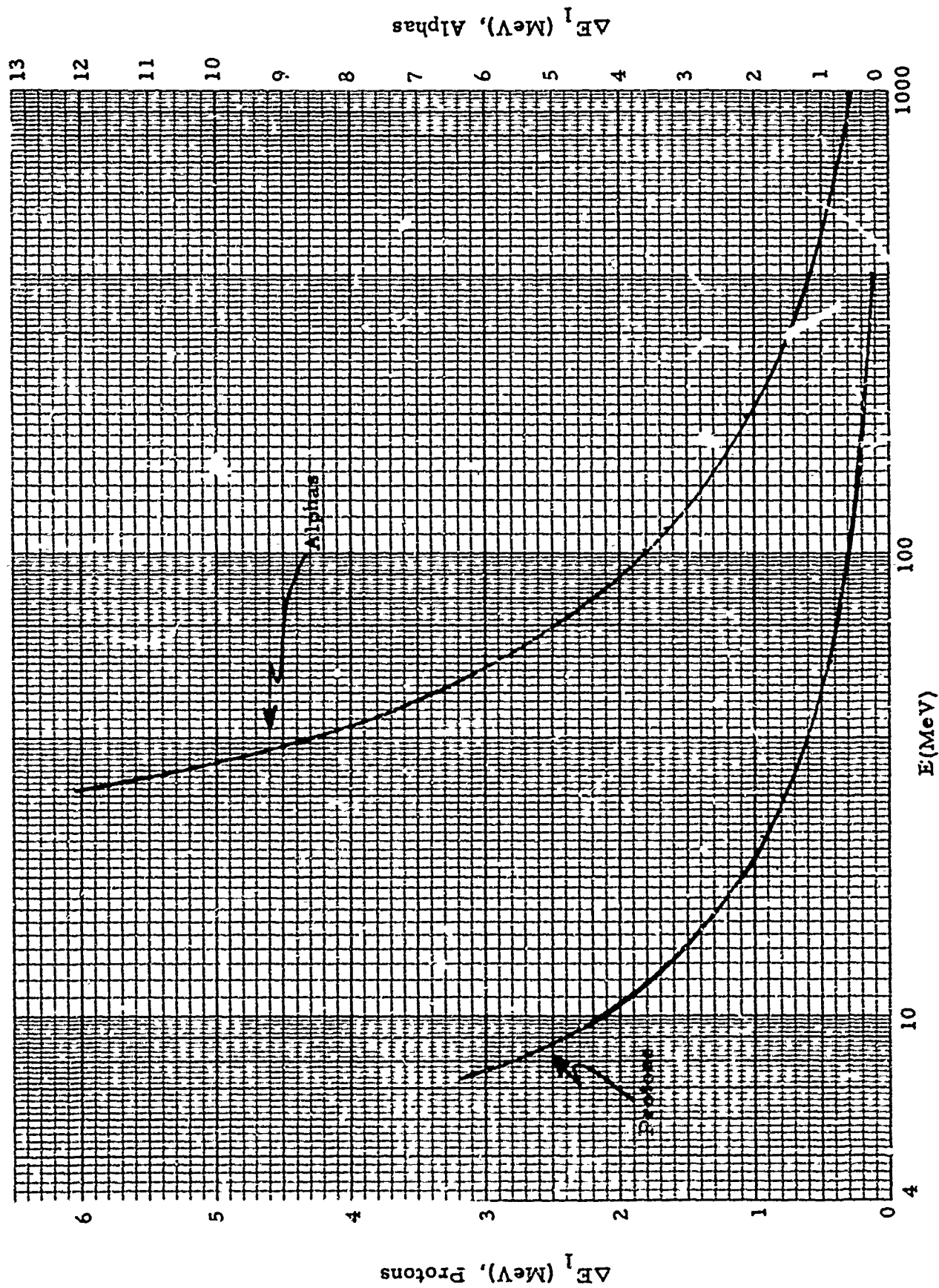
Figure 1.2   Energy Loss in Detector 1, x = 225 microns

7
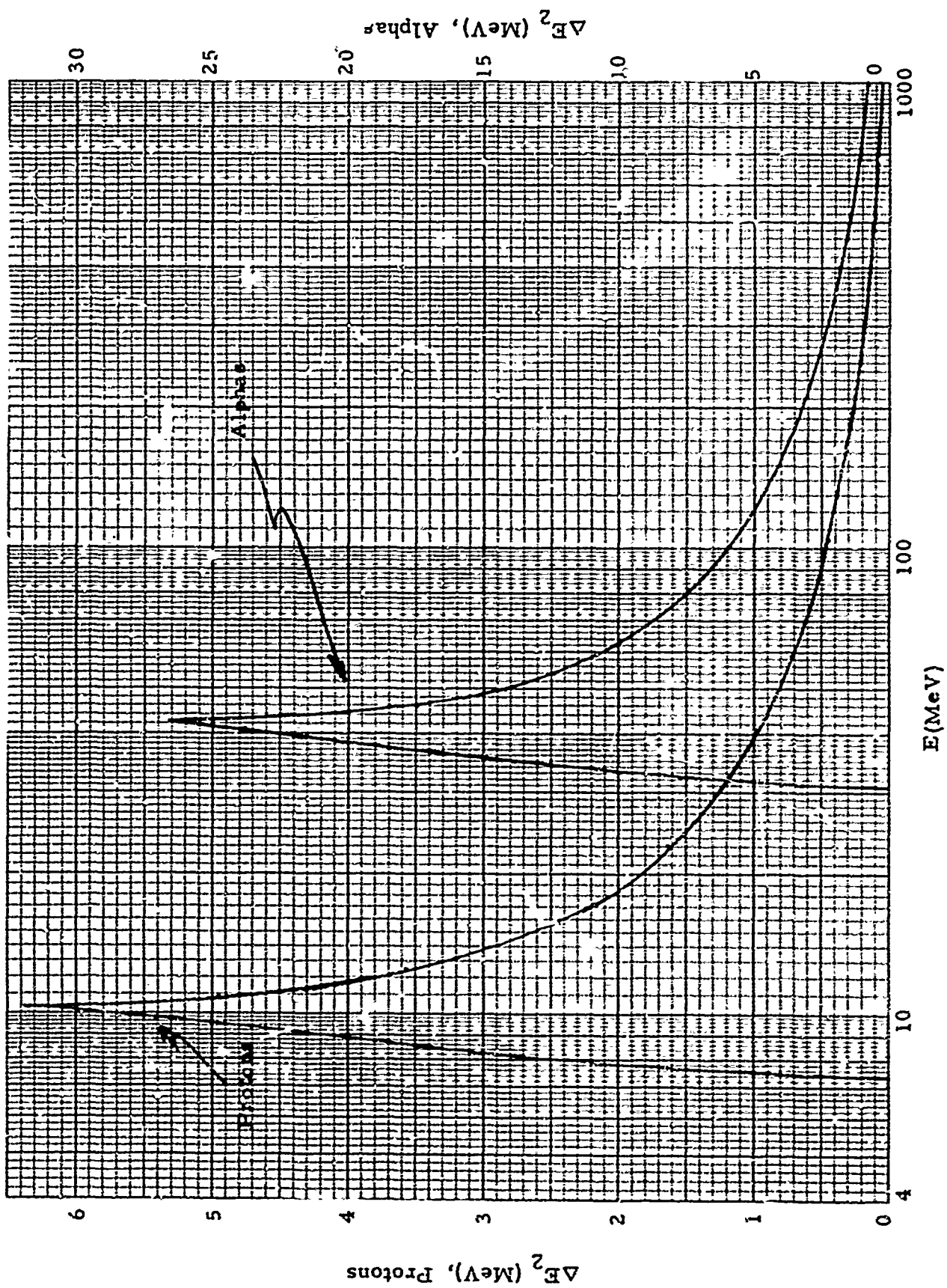
Figure 1.3   Energy Loss in Detector 2, x = 350 microns
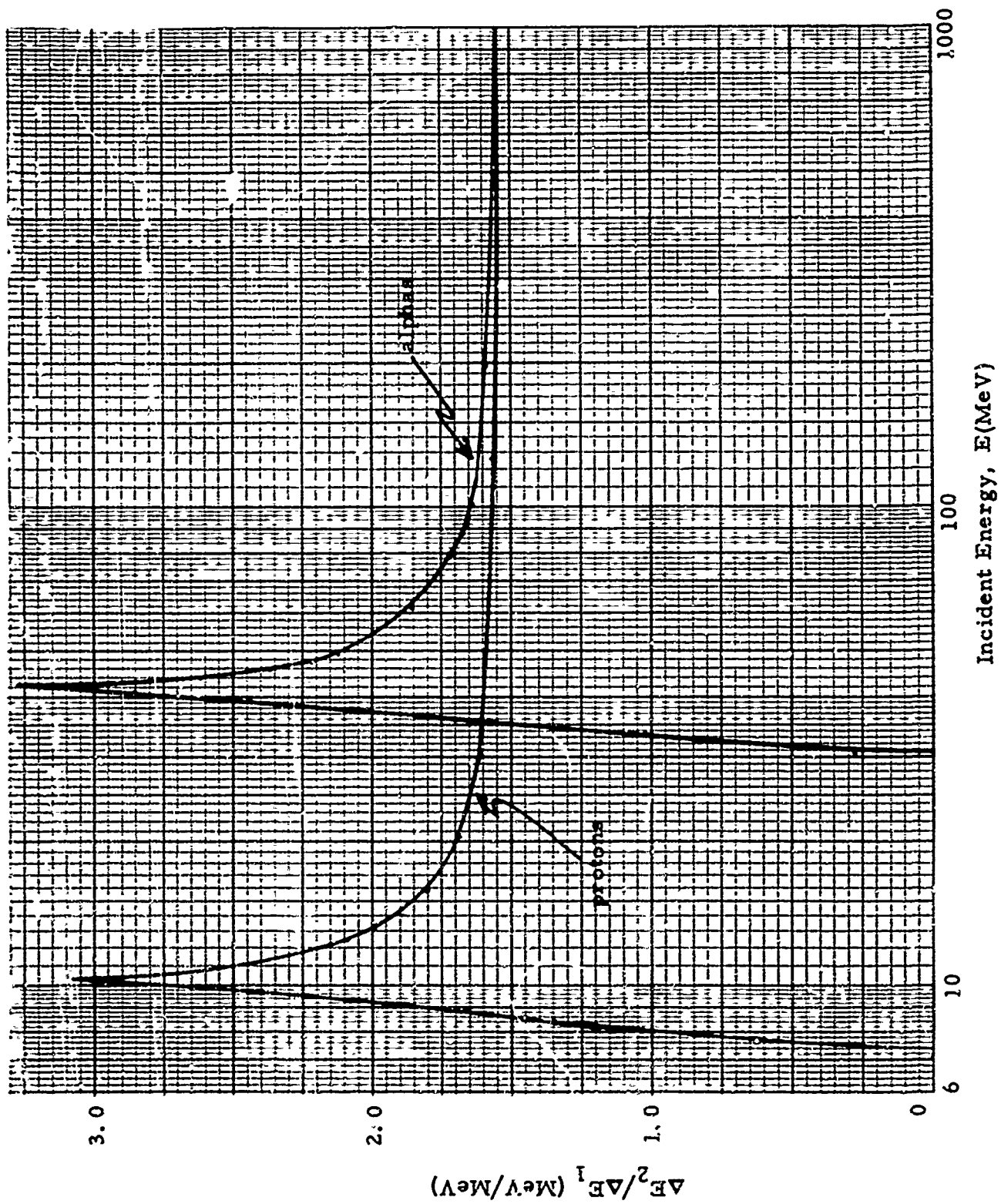
Figure 1.4 Ratio of Energy Deposited in Detectors

9

TABLE 1.1

Preliminary Particle-Energy Distribution Logic

Parameter Range			Particle, Energy Range (MeV)
ΔE_1 MeV	$\Delta E_2/\Delta E_1$ MeV/MeV	ΔE_2 MeV	
>3.5		>6	α, 30-100
>3.5		<6	non-average
1.0-3.5	>1.7	>1.0	p, 7.5-20
1.0-3.5	1.5-1.7	>1.0	α, 100-500
1.0-3.5	<1.5		non-average
1.0-3.5		<1.0	p, 7-7.5
.5-1.0		.9-2.0	p, 20-50, α, 500-1000
.5-1.0		>2, <.9	non-average
<.5		<.9	p, 50-150, α, >1000
<.5		>.9	non-average

Electronic logic requires ΔE_1 and ΔE_2 both greater than about 0.2MeV for coincidence.

for each coincidence. The energy distribution could then be constructed by sorting each particle into energy bins. An alternative to this would be to construct an energy-probability distribution (having integral value unity) for each coincidence and sum all distributions. This would have the advantage that a continuous energy distribution would be generated directly from the input data. Both methods offer advantages and should be studied.

I.2.2 Electronics

The particle detector system consists of a detector assembly, electronics housing, barometric switch and aspect magnetometer. A 28 volt battery pack supplies power to the system as well as to the telemetry transmitter. Power requirement for the payload is 400 mA at 28 volts. The telemetry alone requires 300 mA.

The system is capable of processing deposited particle energies in the range of .2 to 24 MeV. Every particle which deposits an energy within this range in the detectors creates an electrical charge linearly proportional to that energy. In conventional systems the electrical charge is used to transmit pulse height information directly to ground or to sort pulse height by means of window discriminators on board. The first method is subject to telemetry noise, the second has resolution limitations imposed by the available number of telemetry channels. A different approach in data conditioning, more suitable for present IRIG telemetry standards, has been pursued in this Arcas system, by converting pulse height to pulse width. A twofold advantage is realized with this method: (1) the data are relatively unaffected by telemetry noise or linearity, and (2) the received data can be analyzed with a much improved resolution, approaching that of the solid state detector and associated electronics. A system block diagram is given in Fig. 1.5. Two totally depleted silicon semiconductor detectors are arranged in a telescopic manner, as shown in Fig. 1.1, and
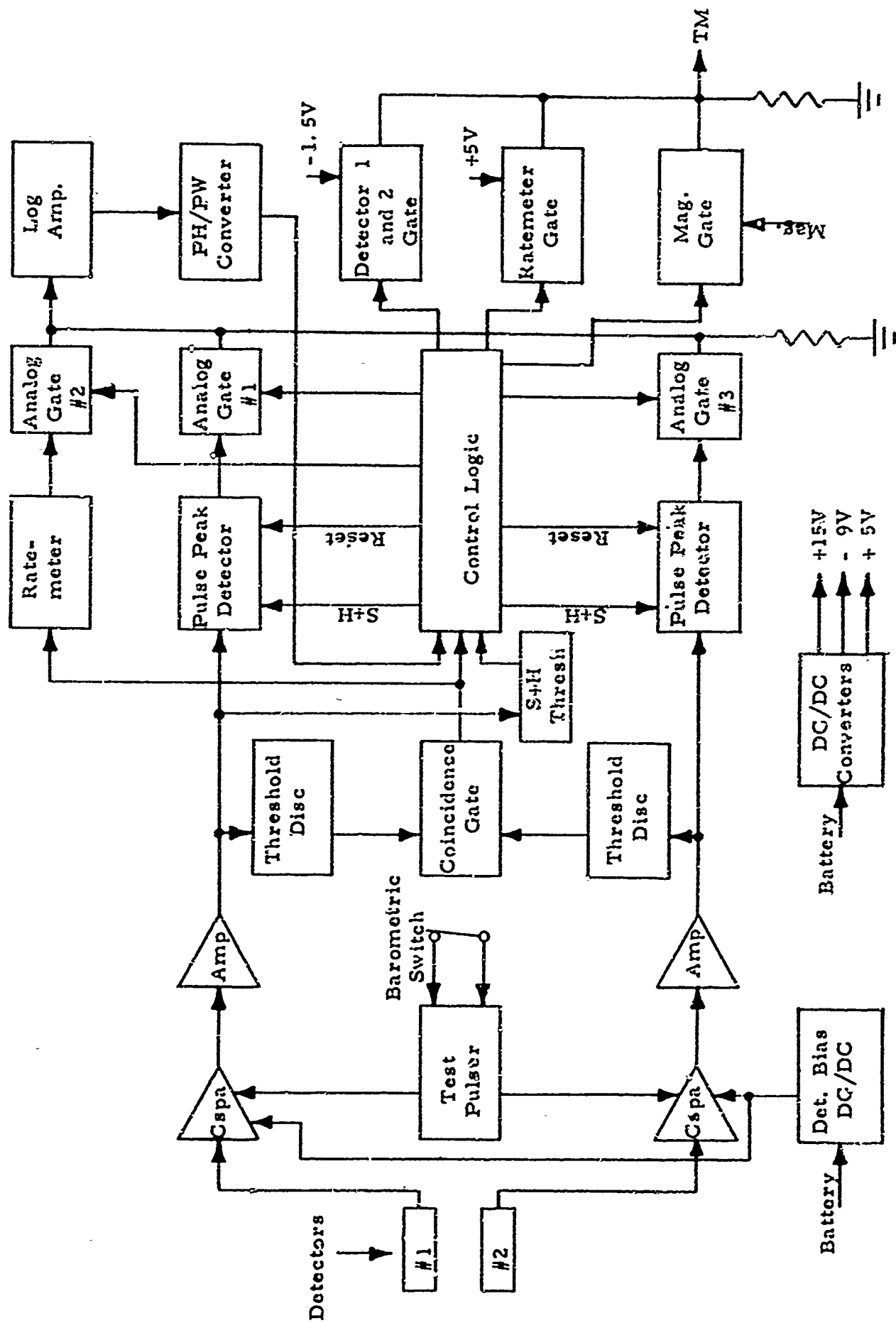
11

Figure 1.5 System Electronics Block Diagram

12

look out the front of the payload. Each detector feeds its own charge sensitive preamplifier, shaping amplifier, threshold discriminator and pulse peak detector.

Also connected to the output of the amplifier of Detector #1, is a threshold discriminator which samples both pulse peak detectors when the deposited energy in Detector #1 is above 150 keV. This is sufficiently above the peak-to-peak electronic noise level so that the pulse peak detector will not be overloaded. As mentioned before, both pulse peak detectors (PPD) are continuously sampled for energies above 150 keV and reset to zero volts after approximately 8 μs. During the sample period the output will reach the peak voltage of the applied amplifier pulse, which is directly proportional to the energy deposited in the detectors. If a charged particle deposits sufficient energy in both detectors to exceed the equivalent threshold voltage of 200 keV, the co-incidence gate will apply a pulse to the count rate meter. Simultaneously the control logic is started, which generates a sequence of command signals as follows: Further sampling and resetting of both PPD's is inhibited and their d. c. outputs are stored. Then analog gate #1 is opened, connecting the stored d. c. level of PPD #1 thru a logarithmic amplifier to the input of the voltage to pulse width converter (DC/PW converter). The resulting pulse width information is fed back to the control logic, where the trailing edge of that pulse initiates the opening of analog gate #2. Con-version of the rate meter output to a pulse width is thus accomplished. At the end of this pulse the same process repeats itself for the PPD #2 output level. Automatically a 200 μs delay is introduced between each conversion as well as at the beginning and end of each sequence by the control logic. Three more outputs provided by the control logic are connected to three multiplex gates. They simply serve to transmit the pulse width informa-tion with identifying amplitudes to telemetry. Pulses originating in Detector

13

#1 or #2 have a -1.5V amplitude and pulses from the ratemeter are provided with a +5V amplitude (see Fig. 1.5). The latter also serves as a calibration voltage for the telemetry. The third multiplex gate is opened at the end of each sequence for a minimum of 0.5 ms, allowing magnetometer signals to be transmitted. At the end of this period the control logic as well as the pulse peak detectors are reset. The system is ready for a new conversion sequence. If no detectable charged particles are present, the magnetometer gate will stay open until a coincidence occurs. At this time a new conversion sequence begins and the magnetometer gate is closed. The telemetry pulses of a sequence are logarithmically related to the deposited energies and count rate respectively. The minimum pulse width however is fixed at 0.5 ms, such that the subcarrier bandwidth of IRIG channel E will not be significantly exceeded. Figure 1.6 shows the above sequence of events as it occurs for each coincidence.

If W(msec) is the pulse width for either detector, the deposited energy ΔE(MeV) is given by

$$\Delta E = \exp(1.60W - 2.40) \tag{1.3}$$

Also, if w(msec) is the pulse width for the ratemeter, the count rate C(kcps) is

$$C = 0.1 \left[\exp(1.60w - 0.8) - 1.0 \right] \tag{1.4}$$

The detectable energy deposition range is 0.2-24 MeV, and the count rate range is 0 to 10 kcps.

Since this payload will not receive the usual preflight checkout of the electronics, an on board test pulser feeding both charge sensitive preamplifiers is included in the system. The pulser is disabled when the contacts of the barometric switch open. Actuation of the switch is set to occur at a pressure-altitude of 75,000 feet. In the absence of radar
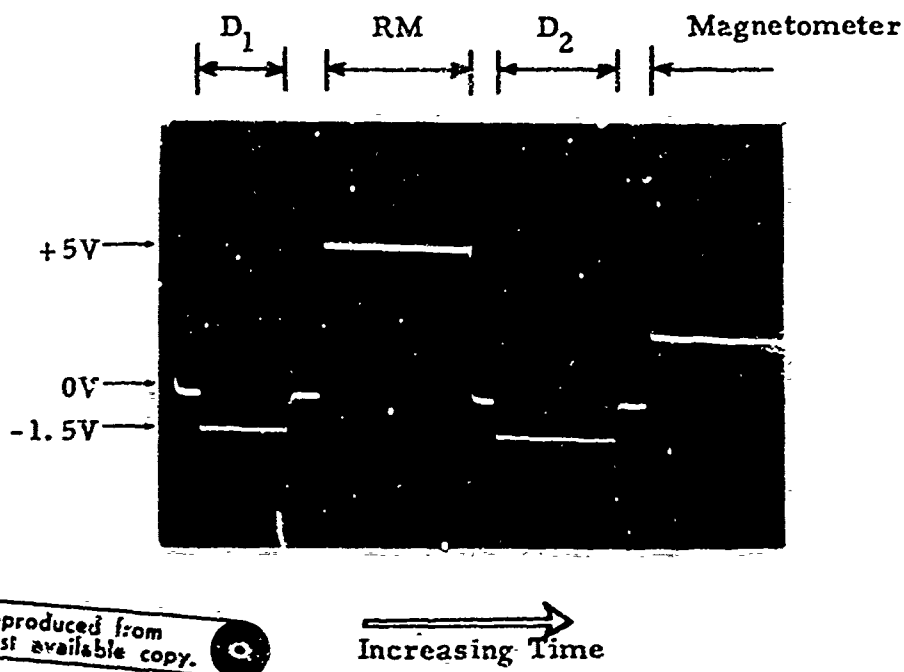
Typical Telemetry signal inputs

D_1 = Detector #1 pulse width, .5 to 3.5 ms

D_2 = Detector #2 pulse width, .5 to 3.5 ms

RM = Ratemeter pulse width, .5 to 3 ms

Figure 1.6

Test Data Oscilloscope Trace of Telemetry Input with Calibration Source

tracking, this will at least provide some altitude information via telemetry both in the ascent and decent stages of the flight.

The detector bias voltage and the supply voltages for the detector electronics are derived from the on board 28V battery through DC/DC converters to conserve power. Idle current of each supply converter is typically 5 mA.

Figures 1.7 and 1.8 show the particle detection electronics and the entire payload.

II. PRELIMINARY EVALUATION OF RESULTS

II.1 System Operation

Two payloads were fabricated under this contract and both were launched successfully at Thule, Greenland. Difficulty with ground receiving equipment, however, prohibited reception of the data for the first shot. The second, from which data were obtained, was fired into a solar particle event on March 29, 1970 at 1034/12 sec U.T.

Although the event was small, it was of sufficient magnitude to be of interest scientifically and to provide a test of the high energy flare particle system. Data were acquired for about 100 seconds total centered about apogee. Typical samples of these data taken from strip charts made from the magnetic tape telemetry record and run at two different speeds are shown in Figs. 2.1 and 2.2. The interference observed was of an undefined nature and was sporadic throughout the flight. It was sufficient to interfere with only a small percentage of particle events. T.M. dropout also occurred sporadically for periods of a few seconds at a time and also for a few milliseconds at certain orientations of the rocket relative to the receiver. The telemetry system clearly requires some improvement. Although the spin rate of the rocket was about 25 rps, Fig. 2.2 shows that the payload functioned generally as expected. The magnetometer output can obviously be utilized to determine

16
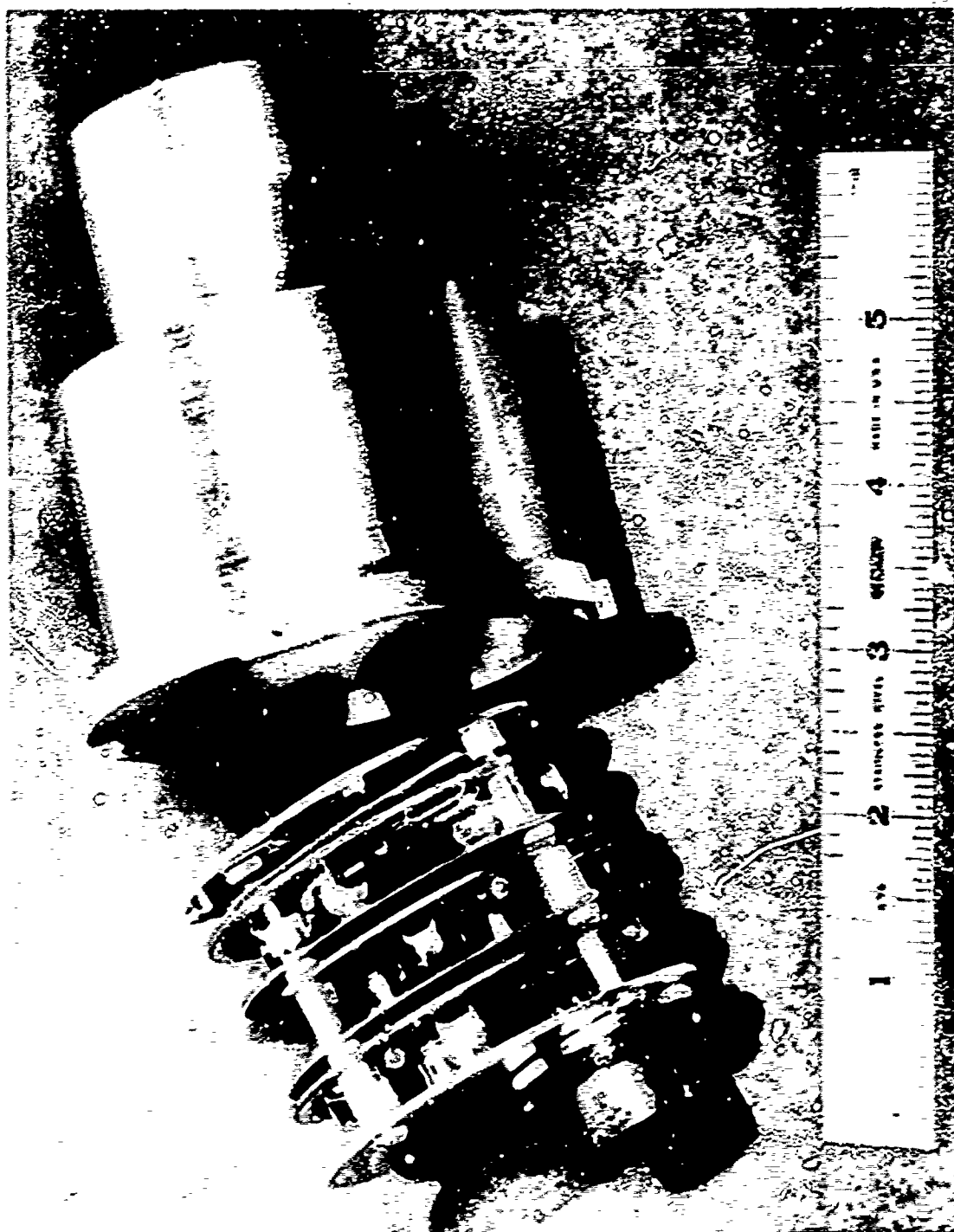
Figure 1.7 High Energy Flare Particle Detection Electronics

17
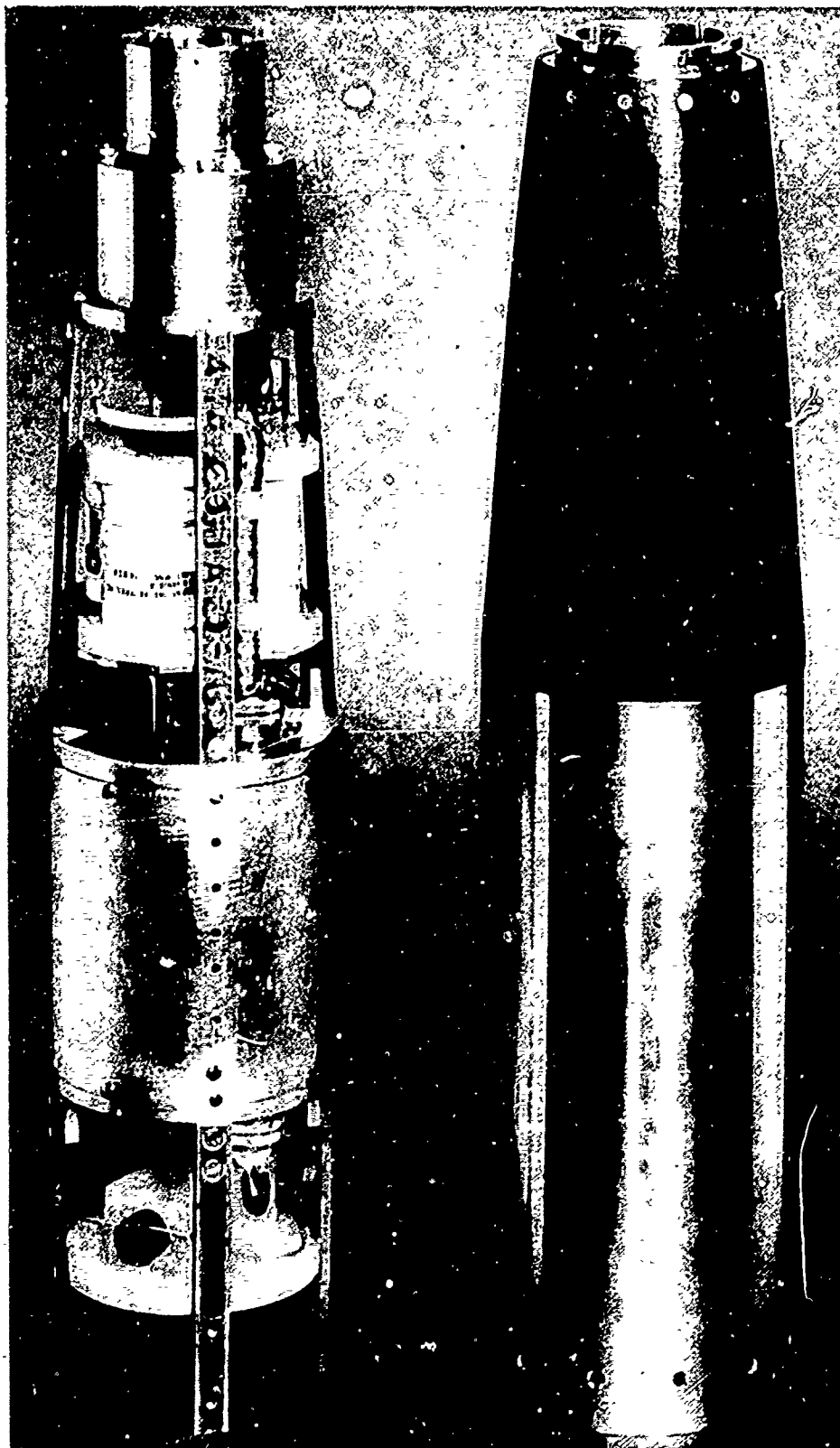
Figure 1.8 High Energy Flare Particle Arcas - Payload and Canister
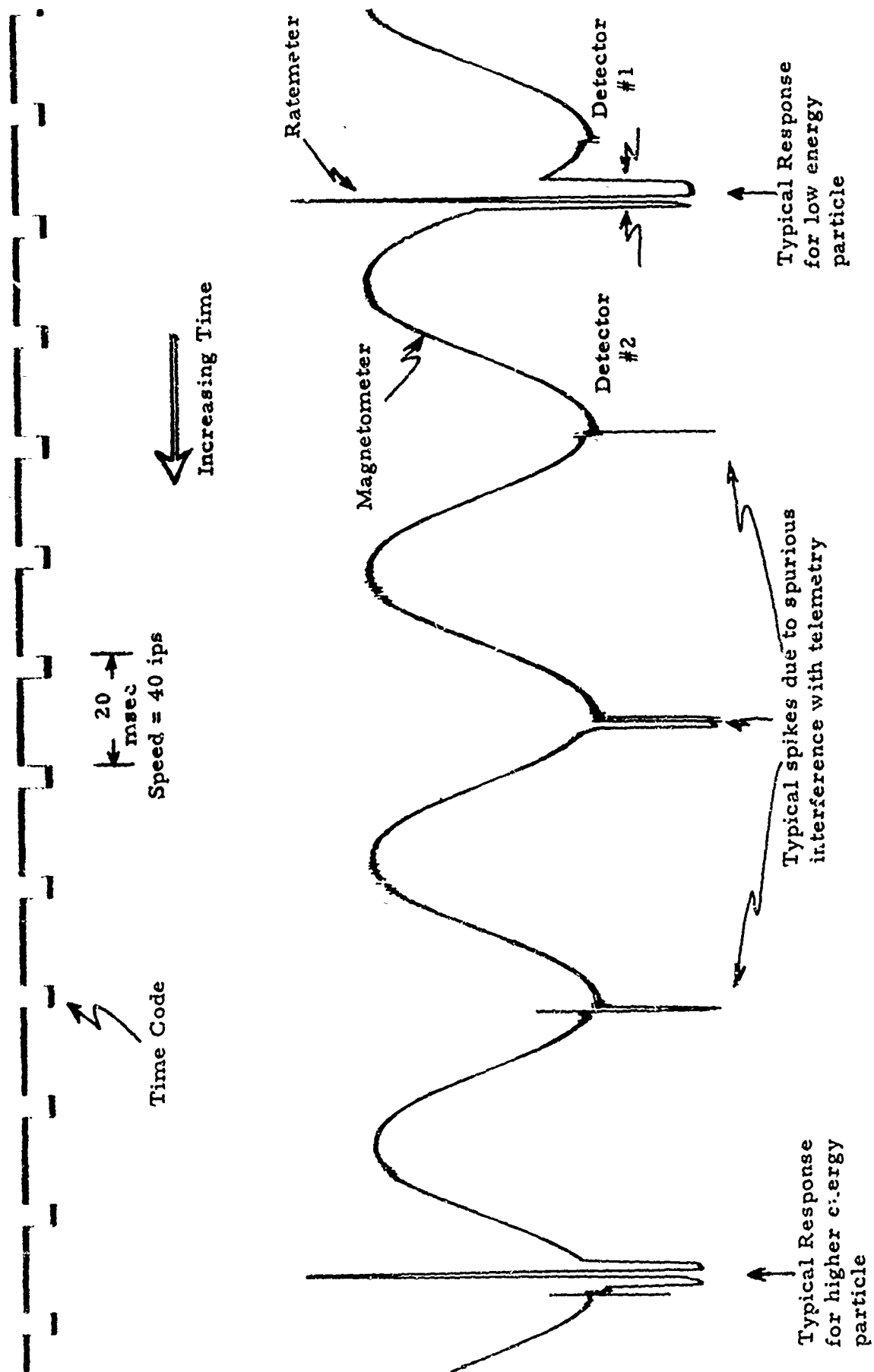
Figure 2.1   Sample of Actual Telemetry Record from Arcas Flight #7921

Ratemeter

Detector #1

Typical Response for low energy particle

Magnetometer

Detector #2

Typical spikes due to spurious interference with telemetry

Increasing Time

20 msec

Speed = 40 ips

Time Code

Typical Response for higher energy particle

19

Increasing time

Ratemeter

Magnetometer

Detector 1

Detector 2

Figure 2.2   Sample of T. M. Record at 160 i. p. s.

the direction of arrival of the particles. The width of the ratemeter pulse is 0.5 msec, and it remained that way throughout the flight.

An examination of the strip charts for the entire 100 seconds spent above about 50 km shows that only about 200 particles were observed,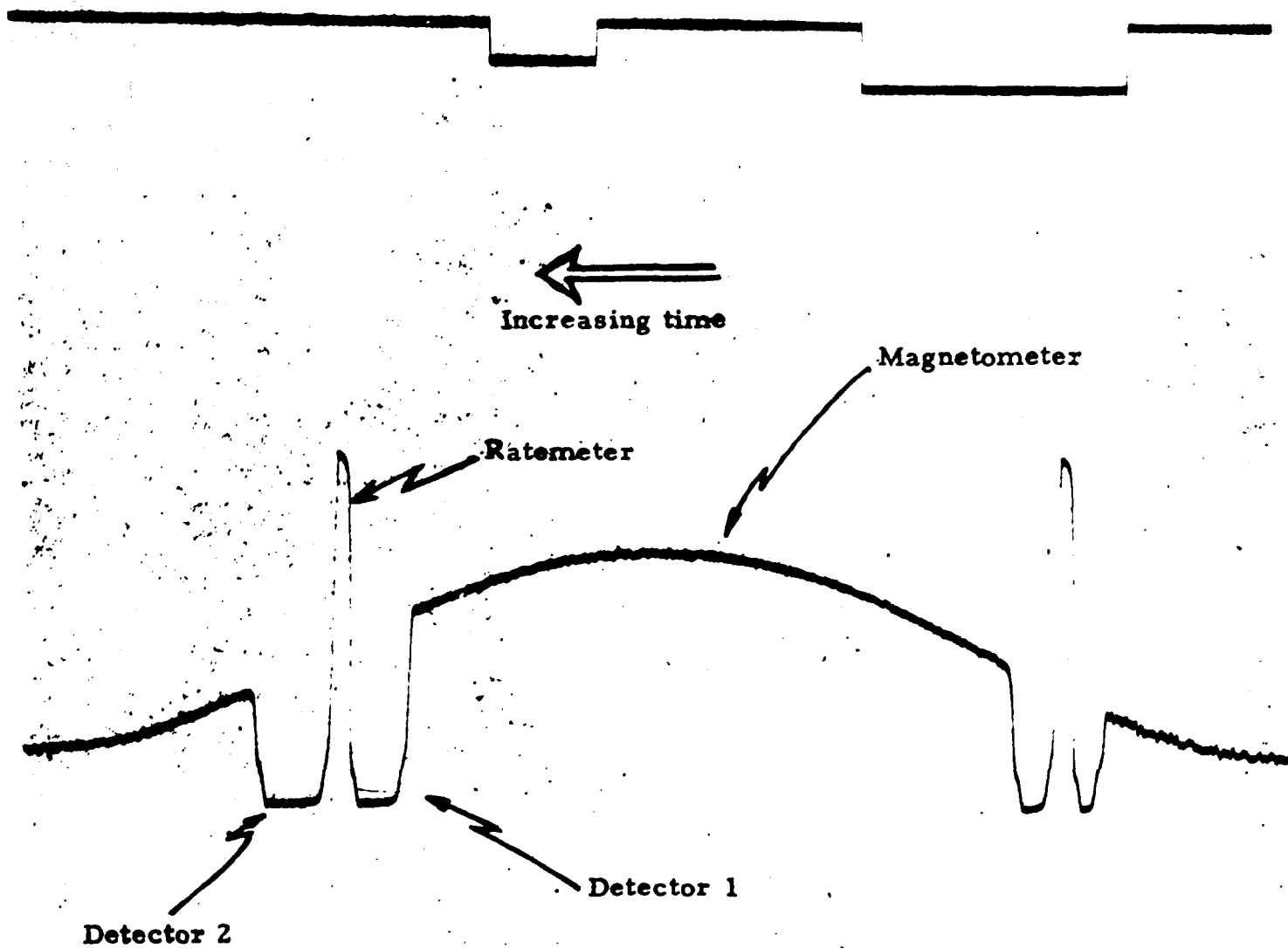 with the rate being highest near apogee, which occurred at about 70 km. To illustrate the data reduction method the strip charts were used to make a rough measurement of the (time) width of the detector pulses and Eq. (1.3) is used to compute ΔE. For example, consider the two particle events in Fig. 2.2. The left-hand event has widths of about 1.56 msec and 2.15 msec, corresponding to 1.1 MeV and 2.8 MeV deposited in Detectors 1 and 2, respectively. Since $\Delta E_2/\Delta E_1 \approx 2.65$, reference to Table 1.1 shows that this corresponds to a proton in the energy range 7.5-20 MeV. The right-hand event yields about .23 MeV and .43 MeV deposited in 1 and 2, respectively. Table 1.1 shows this to correspond to either a proton in the range 50-150 MeV, or an alpha of energy > 1000 MeV.

Approximately 50 events during a 26 second period were examined by the above method; only two were identified as definitely being alphas by use of the criteria in Table 1.1. It appears that about 5-10% of the events will be of the "non-average" type that cannot be used in determining the energy distribution. Since the total number of protons observed was 48, use of (1.1) and (1.2) gives

$$I(>7) = 2.3 \pm .3 \; p/(cm^2\text{-sec-sr}) \qquad (2.1)$$

as a preliminary estimate of the integral flux for protons having energies exceeding 7 MeV at the point of observation. Noting that the range-altitude of a $0°$ pitch angle proton of 10 MeV energy is about 60 km, and that of a 20 MeV proton is about 50 km, it is clear that the integral flux given by (2.1) must be associated with a lower limit of about 10-20 MeV on the incident spectrum. (The manner of deducing the actual incident spectrum from the particles observed at various altitudes and pitch angles is

considered below.) In general it can be stated that, electronically, the system functioned as intended and the quality of the data was high.

II. 2 Recommended Data Reduction Procedure

In summary, about 200 particle events were observed in the 100 second period centered near apogee. Of these about 10% cannot be used for determining the spectrum shape. The remainder should be examined event by event and sorted to determine the most probable event energy for each. A pitch angle and altitude is then associated with each event by use of the magnetometer, which allows a calculation of path length from outer space to the point of observation for each event. Using this path length the incident energy at the top of the atmosphere required to produce the observed energy should be determined for each event. The result is a tabulation of all events, each having an associated incident energy. The technique presented in Section I should be extended and investigated in order to determine the optimum method of identifying the particles and generating the energy distribution function.

III. A NOTE ON ASYMMETRIC ACCESS OF PARTICLES AT POLES

During the time of launch of the ARCAS Proton Payload (1034 U.T., 29 March 1970) at Thule, the satellite Explorer-41 (IMP-G) was well outside the magnetosphere and measured interplanetary fluxes. These fluxes show a fast rise starting at about 0200 and a relatively flat plateau from about 0400 to 2300, followed by decay. The EXP-41 data give integral fluxes above thresholds of 10, 30 and 60 MeV, and in the period 1000-1200 they are approximately (Ref. 3.1, p 88-90):

$$\left. \begin{array}{l} I\,(>10)\ =\ 42.5\ p/(cm^2\text{-sec-sr}) \\ I\,(>30)\ =\ 15.4\ p/(cm^2\text{-sec-sr}) \\ I\,(>60)\ =\ \ 6.2\ p/(cm^2\text{-sec-sr}) \end{array} \right\} \qquad (3.1)$$

These measurements indicate a value for $I\,(>20)$ of about 20 $p/(cm^2\text{-sec-sr})$. If, as suggested above, the value (2.1) measured by the ARCAS is associated

with a threshold of 10-20 MeV, then these results indicate that at Thule, near the North magnetic pole, the proton flux was 10 to 20 times less that in interplanetary space. This is consistent with satellite measurements reported by Evans and Stone (Ref. 3.2), and by VanAllen, et al. (Ref. 3.3), who found that the central portion of one polar cap could have as much as 30 times less flux for protons of a few MeV as the other polar cap and interplanetary space.

Measurements on electrons indicate access times to the magneto-tail of < 100 sec (Ref. 3.4) and symmetric precipitation over the poles (Ref. 3.5). Electron and proton precipitation over the polar caps is thus quite different.

The preceding discussion shows that polar cap precipitation of solar particles can be quite variable according to particle type. The early time absorption of a PCA may be due, to a significant extent, to electrons, and thus tend toward symmetry for North and South polar caps. The later time absorption may be confined predominantly to one pole, tending to decay toward symmetry within 10 to 20 hours. A simultaneous measurement of particle (mostly of proton) fluxes near the two geomagnetic poles early in a PCA event (a few hours after onset) may thus provide good information on whether both polar caps will be equally affected by the ensuing PCA.

The ARCAS Proton Payload would provide a good method of measuring the North-South asymmetry. The payloads could be set up near both geomagnetic poles and upon notice fired within a few minutes of each other. It should be noted that near the edge of the polar caps the measured fluxes tend to have the maximum value found in the polar caps, and to be close to the interplanetary value. Thus a simultaneous launch at (say) Thule (near the geomagnetic pole) and at Ft. Churchill (near the edge of the polar cap) would provide evidence for a lower North pole absorption. However, such a one-pole measurement could not decide whether the opposite pole had a lower absorption if the two rockets measured equal fluxes, so, if possible, a two pole launch would be desirable.

23

IV. CONCLUSIONS AND RECOMMENDATIONS

The high energy flare particle ARCAS payload functioned generally as anticipated, and a successful firing was made into a small event, as observed at Thule. The vehicle had been on-site for several months prior to launch. The decision to fire was made remotely and simple tests were performed by range personnel to ascertain proper payload operation just prior to launch. Thus, a complete test of the remote firing concept was accomplished. The data obtained were of a high quality and indicate that the system is capable of providing the desired incident spectra, for both protons and alphas, from which the various ionospheric effects can be calculated.

It is recommended that the remaining data be analyzed for this event and that further flights be carried out both for study of ionospheric effects and the North-South asymmetry in incident fluxes.

REFERENCES

3.1 "Solar Geophysical Data," ed. by H. I. Leighton and J. V. Lincoln, ESSA, Sept. 1970, No. 313, Part II.

3.2 L. C. Evans and E. C. Stone, "Access of Solar Protons into the Polar Cap: A Persistent North-South Asymmetry," J. Geophys. Res., 74, 5127 (1969).

3.3 J. A. VanAllen, J. F. Fennell, and N. F. Ness, "Asymmetric Access of Energetic Solar Protons to the Earth's North and South Polar Caps," J. Geophys. Res., 76, 4262 (1971).

3.4 J. A. VanAllen, "On the Electric Field in the Earth's Distant Magnetotail," J. Geophys. Res., 75, 29 (1970).

3.5 H. I. West, Jr. and A. L. Vampola, "Simultaneous Observations of Solar Flare Electron Spectra in Interplanetary Space and Within Earth's Magnetosphere," Phys. Rev. Lett., 26, 458 (1971).